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MOVEMENT OF GAG, *MYCTEROPERCA MICROLEPIS,* IN AND FROM ST. ANDREW BAY, FLORIDA

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ABSTRACT

In this study, we investigated movements of gag, *Mycteroperca microlepis,* in a deep, high salinity embayment in the northeastern Gulf of Mexico from August 1994 through August 1996. Two hundred-fifty gag were captured in traps, tagged with internal anchor tags, and released into St. Andrew Bay, Florida. One hundred thirty-two (52.8%) tagged gag were recaptured by recreational anglers and by project personnel. Only 14.3% of gag moved from their release sites, with the distance moved averaging 2.38 km (east and southeast) within the bay. Six large gag (>500 mm total length) moved from 9 to 458 km out of the bay, presumably to recruit to offshore spawning stocks. Recaptured gag were free up to 645 d. Analysis of variance (ANOVA) of distance moved by gag revealed that days free was a significant effect in the model, but total length was not.

Gag, *Mycteroperca microlepis,* are important recreational and commercial fishes in the Gulf of Mexico (Smith, 1971, 1978; Hardy, 1978). Adults are frequently found on offshore reefs, with sexually mature gag annually traveling extensive distances offshore on the continental shelf to spawn (Van Sant et al., 1990; Coleman et al., 1996). From these offshore spawning areas, larvae are transported inshore by ocean currents, where they become demersal (Manooch and Haimovici, 1978; Manooch, 1987; Grimes, 1987; Van Sant et al., 1990; Coleman et al., 1996; Collins et al., in review). Historically, juvenile gag have been observed in both offshore and inshore waters (Hoese et al., 1961; Ingle et al., 1961; McErlean, 1963; Adams, 1976), but their inshore to offshore movements were not documented until 1978 (Manooch and Haimovici, 1978). Although movement offshore of gag and other related species has been examined (Beaumariage and Wittich, 1966; Moe, 1966; Moe et al., 1970; Leggett, 1977; Fable, 1980; Parker, 1990; Van Sant et al., 1990), there is a paucity of research on movements within and from estuaries (Topp, 1963; Funicelli et al., 1986; Bryant et al., 1989; Bullock and Smith, 1991). The extent to which juveniles migrate offshore at the onset of their first winter, as well as the magnitude and direction of these movements is largely unknown. Attempting to answer these questions, we conducted a mark-recapture study of gag in St. Andrew Bay, Florida.

MATERIALS AND METHODS

STUDY AREA.—St. Andrew Bay (SAB) is located in northwest Florida (Fig. 1) and encompasses 280 km^2; average and maximum depth are 5.2 and 19.8 m, respectively. A deep (mean = 28.0 m) and wide (mean = 144.8 m) pass provides a connection to the Gulf of Mexico, providing appreciable tidal flow. Bottom salinities in SAB usually exceed 30‰ (McNulty et al., 1972; Brusher and Ogren, 1976; Pristas and Trent, 1977). Juvenile and adult gag are often reported associating with many of the artificial structures present within the south-central region of SAB. These artificial structures include concrete docks, rock jetties, sunken boats, and wooden navigational markers. Seventeen of these structures were selected as trapping sites (mean depth = 5.2 m) (Fig. 1).

METHODOLOGY.—Fish were captured in "heart-shaped" wire-mesh traps measuring 222 × 76 × 62 cm with a mesh size of 3.5 × 3.5 cm. Traps were baited with frozen squid and round scad and placed near each structure. They were retrieved, emptied, and rebaited every 24 h. Gag were removed from traps and placed into a tagging cradle (described by Fable, 1980), measured for total length (TL), tagged with internal anchor tags and released. All other species were released.

Internal anchor tags (oval anchors 29 × 9 mm, with streamers 55 mm long displaying the tag number and a reward message) were inserted into the abdominal cavity, approximately 1 cm posterior

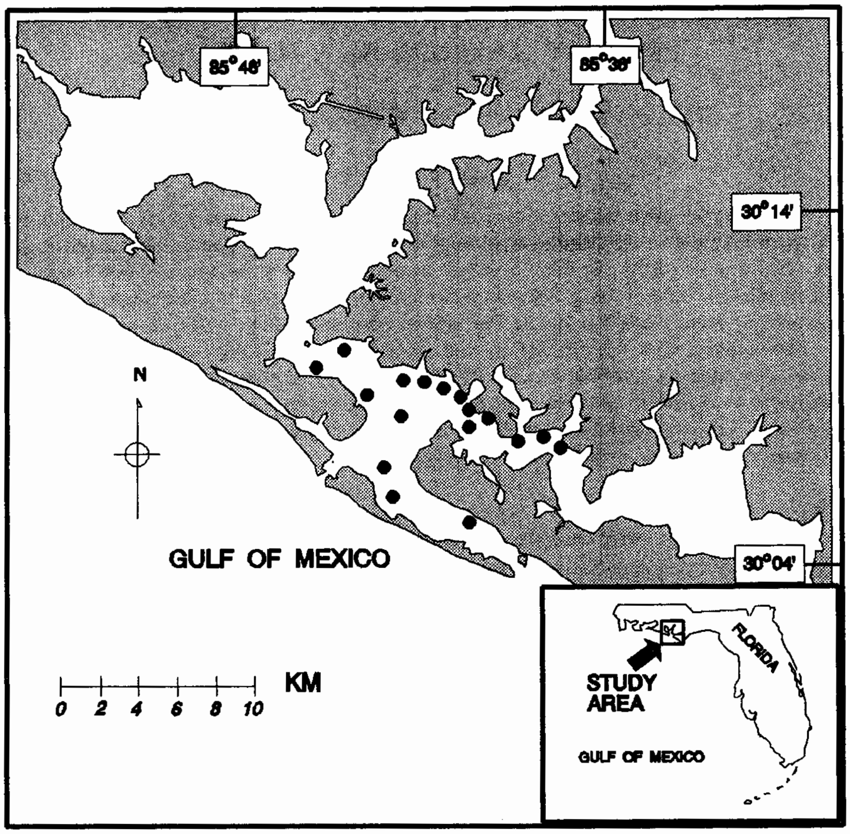

Figure 1. Location of St. Andrew Bay, Florida, tagging and release sites of gag (*Mycteroperca microlepis*).

to the pelvic fin and 0.5 cm lateral of the ventral midline. After tag insertion, streamers were lightly pulled to ensure proper setting of the anchors before releasing the fish.

Fish re-caught in our traps were recorded and re-released. Posters advertising random reward amounts ranging from $5–$25 for recaptured fish were distributed and displayed at tackle shops and marinas. Tag number, location and date of capture, and tag wound condition data were obtained from angler telephone interviews and letters.

Movement distance was calculated using straight-line measurements from tagging sites to recapture sites. Tag wound condition was also evaluated by necropsies performed on three returned whole gag. Bottom water temperatures were recorded monthly at trapping/tagging sites in SAB during the study period by members of the St. Andrew Bay Resource Management Association. Recapture data were analyzed using ANOVA. Distances moved with total length at capture and number of days free were utilized as main effects in the model.

Results

Two hundred and fifty gag (240–800 mm TL, mean TL = 364 mm) were captured, tagged, and released into SAB from August through October 1994 (Fig. 2). A total of 132 tagged gag were returned, 54 (21.6%) by fishermen and 78 (31.2%) as a result of our further trapping, for an overall return rate of 52.8%. Multiple recaptures of the same individual were not considered in overall return rate. Five gag were recaptured as many as six times in traps at the same location for the first 6 mo of the study.

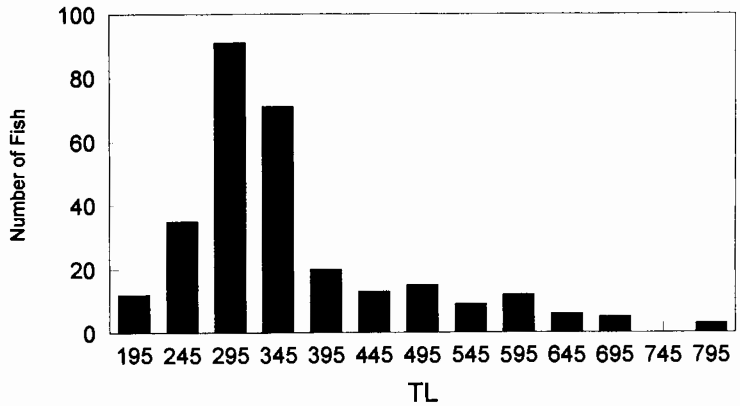

Figure 2. Size-frequency of tagged gag (*Mycteroperca microlepis*) in St. Andrew Bay, Florida.

No apparent mortality was associated with trapping and tagging. Tag wounds on recaptured fish healed externally to a scar, whereas the internal musculature surrounding the internal anchor on several fish exhibited a dark envelope of tissue as described by Mattson et al. (1988). Several tag streamers on fish at liberty for long periods of time (>90 d) were obscured by a dark mass of tissue originating at the streamer base. Damage to tags included bite marks, scraped off letters, and severed streamers.

Most gag (85.7%) were recaptured at their tagging location during the study period. Other gag (n = 19) moved 0.3–458.0 km away from the initial tagging site (Fig. 3A,B, Table 1), primarily to the deeper southwest waters of SAB. Tagged gag were free as long as 645 d. ANOVA of distance moved revealed that days of freedom was a significant effect in the model ($P < 0.01$), but TL was not (Table 2).

Growth rates were obtained from multiple recaptures of 23 trapped gag (Table 3). These gag, ranging in size from 260–520 mm TL at tagging, exhibited a mean increase in TL of 0.31 mm d^{-1} (min = 0.07; max = 0.68 mm d^{-1}).

Bottom water temperatures in SAB ranged from 9.0–29.0°C during the study. In winter (December–February), bottom water temperatures ranged from 9.0–16.5°C in upper SAB and ranged from 11.5–16.5°C near the pass.

Discussion

We believe some small gag that would move offshore from shallow areas during colder months in other embayments remain within the deeper/warmer areas of SAB. St. Andrew Bay, unlike other shallow estuaries, contains deep areas (>13 m) that are less affected by winter temperatures. In addition, the minimum depth of the pass connecting SAB to the Gulf of Mexico is 13.4 m, permitting appreciable tidal flow of warmer offshore water into the bay during winter. Bottom water temperatures in the deeper areas of SAB (e.g., near the pass) did not cool below 11.5°C during the study period, however, shallower areas of the bay cooled to as low as 9°C (SABRMA 1995; SABRMA Lake/Baywatch Water Monitoring Program Database, % D. Peck, Panama City Beach, Florida, unpub. data). Movement to the pass was apparent as several gag (n = 8) tagged on structures north of the pass during August, September, and October were recaptured 2 to 6 mo later at structures adjacent to or in the pass. Gag tagged on structures near the

A.

B.

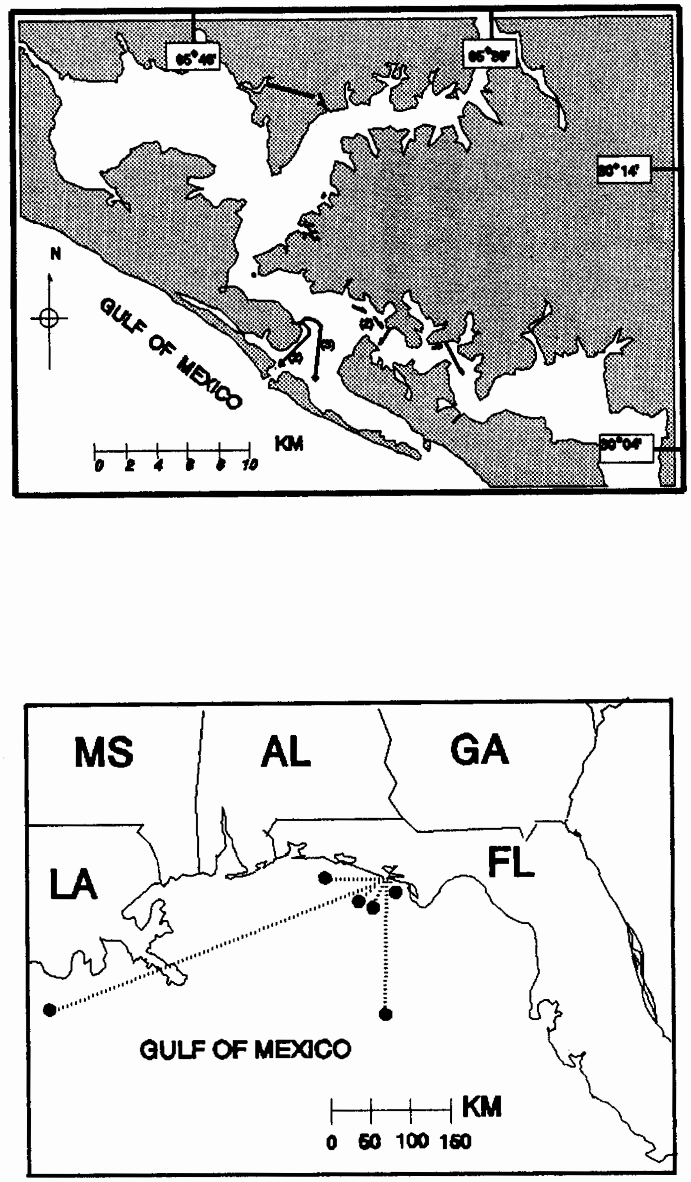

Figure 3A. Movement of gag (*Mycteroperca microlepis*) within St. Andrew Bay, Florida. Solid arrows represent gag movement. Numbers in parentheses beside arrow indicate movement of more than one individual in the direction of the arrow. Figure 3B. Offshore movement of tagged gag (*Mycteroperca microlepis*) from St. Andrew Bay, Florida.

pass were recaptured there year-round for over 1 yr. This type of seasonal movement pattern for juvenile gag is similar to that observed by Hastings (1979) at the pass jetty in SAB and by Parker (1990) on shallow water reefs off South Carolina.

We also believe that the larger gag that moved appreciable distances were migrating to or from spawning areas. Our results indicated that six large gag

Table 1. Summary of recapture information for 6 individual tagged gag (*Mycteroperca microlepis*) which migrated offshore from St. Andrew Bay, Florida. Date tagged (DATE (T)), total length at tagging (TL (T)), date recaptured (DATE (R)), total length at recapture (TL (R)), and days of freedom (DOF) along with distance and direction information are presented. N/A = not available.

DATE (T)	TL (T)	DATE (R)	TL (R)	DOF	Distance moved (km)	Direction
08/23/94	660	09/28/95	N/A	401	458.0	WSW
09/02/94	330	05/27/96	508	633	56.3	SW
09/20/94	260	04/22/96	563	548	104.0	S
10/18/94	610	12/27/94	N/A	77	19.2	SE
10/18/94	720	05/07/96	863	566	56.3	SW
10/25/94	380	08/02/96	635	645	81.5	W

(>500 mm TL at recapture) moved offshore and were recaptured at depths ranging from 26 to 81 m just prior to, during or just after the spawning season. The location and depth of these recapture sites and the time of year of recapture suggest these fish could have been migrating to or from spawning areas. Similarly, other studies have found that large gag moved great distances offshore to known spawning areas (Collins et al., 1987; Van Sant et al., 1990; Bullock and Smith, 1991). Van Sant et al. (1990) stated that "since peak spawning of gag in this region takes place during February–April, migration [during this time] may be related to spawning activity... ". Gag become sexually mature as early as 3 yrs of age and 400 mm TL (McErlean and Smith, 1964; Collins et al., 1987; Bullock and Smith, 1991; Hood and Schlieder, 1992) and spawn at depths ranging from 50–120 m (Coleman et al., 1996). The smallest gag recaptured offshore was recovered on 22 March 1996, 104 km south of SAB in 82 m of water along with a group of actively spawning females. Histological examination of this 563 mm TL (at recapture) individual indicated that it was a sexually immature female. This was not surprising as immature female gag are often found with spawning gag in aggregations (Coleman et al., 1996; L. A. Collins, National Marine Fisheries Service, 3500 Delwood Beach Road, Panama City Beach, Florida 32408, unpubl. data). ANOVA revealed that the number of days at liberty was significant, however, TL at recapture was not significantly related to distance moved. Tagged gag were at liberty for up to 645 d; during which time some appeared to move extensively and others not at all. It is not known why some individuals of approximately the same size migrated extensive distances offshore and others appeared to remain in the bay. One possible explanation for these apparently sedentary large gag recaptured in the bay after or before the spawning season is that they may have migrated offshore and returned to their original tagging site.

Tagging probably did not have significant physical or physiological effects on the fish, as growth rates calculated from recaptured gag suggest normal growth. Growth estimates for tagged gag varied considerably (range = 0.07–0.68 mm d^{-1};

Table 2. Two-way ANOVA on movement of all recaptured gag (*Mycteroperca microlepis*) tagged and released into St. Andrew Bay with total distance moved (km) as the dependent variable. F-values and probabilities are from Type II sum of squares. * denotes significant effects.

Source	F-value	PR>F
Total Length at Recapture (TL (R))	3.18	0.0756
Days of Freedom (DOF)	46.68	0.0001*
TL (R) × DOF	2.73	0.0995

Table 3. Growth rate information obtained from recaptures of tagged gag (*Mycteroperca microlepis*) released into St. Andrew Bay, Florida. Tag number, date taggged (DATE (T)), total length at tagging (TL (T)), date recaptured (DATE (R)), total length at recapture (TL (R)), length change, and growth rate information are provided. All lengths are in mm.

Tag no.	Date (T)	TL (T)	Date (R)	TL (R)	Length change	Growth rate
15,901	09/02/94	345	12/13/94	414	69	0.68 mm/d
15,963	09/09/94	360	12/13/94	398	38	0.40 mm/d
15,994	09/09/94	520	12/13/94	571	51	0.54 mm/d
10,154	09/20/94	260	04/22/96	563	303	0.58 mm/d
15,687	10/05/94	320	12/13/94	352	32	0.46 mm/d
			12/13/95	514	162	0.44 mm/d
15,980	10/05/94	290	12/13/94	325	35	0.51 mm/d
15,691	10/05/94	320	12/15/94	344	24	0.34 mm/d
15,677	10/05/94	315	12/15/94	326	11	0.15 mm/d
15,707	10/06/94	335	12/13/94	365	30	0.44 mm/d
15,715	10/06/94	305	12/14/94	347	42	0.61 mm/d
			03/28/95	362	15	0.14 mm/d
15,704	10/06/94	375	05/04/96	546	171	0.31 mm/d
15,720	10/12/94	505	08/12/95	610	105	0.35 mm/d
15,667	10/13/94	335	03/31/95	347	12	0.07 mm/d
15,737	10/13/94	310	12/15/94	317	7	0.11 mm/d
			03/28/95	339	22	0.21 mm/d
15,714	10/13/94	295	12/15/94	314	19	0.30 mm/d
			03/28/94	318	4	0.10 mm/d
15,718	10/13/94	342	12/15/94	359	17	0.27 mm/d
15,683	10/13/94	325	03/31/95	347	22	0.14 mm/d
			12/13/95	398	51	0.22 mm/d
15,728	10/13/94	340	12/15/94	346	6	0.09 mm/d
			03/28/95	350	4	0.10 mm/d
10,320	10/18/94	720	05/07/96	863	143	0.25 mm/d
15,739	10/20/94	315	12/15/94	321	6	0.11 mm/d
			03/29/95	325	4	0.08 mm/d
15,987	10/20/94	355	12/15/94	365	10	0.18 mm/d
			03/29/95	380	15	0.32 mm/d
15,736	10/21/94	385	03/28/95	424	39	0.24 mm/d
15,940	10/25/94	380	08/02/96	635	255	0.37 mm/d

mean = 0.42 mm d^{-1}; SD = 0.23 mm d^{-1}), probably due to time (month) of tagging, TL of individual fish at tagging and other environmental factors. Highest growth rates were recorded from smaller fish (TL <350 mm) that were tagged early in the fall. We compared our growth estimates by matching the TL of our tagged gag to the otolith derived estimates of Johnson et al. (1993) of lengths at age for gag to estimate the age of our gag. Using this method, gag in this study were estimated to be ages 0–5 yrs. Our overall growth rate of 0.31 mm d^{-1} compares well to Johnson's mean daily growth rate of 0.45 mm d^{-1} for gag age 0–5 yrs.

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